# SUPPORT TOOLS FOR BUILDING THERMAL REHABILITATION

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**Abstract**

Countries development led to an increase use of energy resources that are essential to social and economic welfare of populations but damage the environment. This raise in energy use originated the increase of greenhouse gases emissions and the consequent climatic changes we all assist.
Since only recently sustainability and energy efficiency issues have gained special relevance, especially in the Portuguese context, there is a great potential for the development of methodologies and strategies to improve the energy efficiency of buildings and to diagnose and repair thermal pathologies.
The Mediterranean area, in which Portugal is included, is a privileged area when compared with other parts of Europe because of its mild climate. However, buildings show very high heating needs and unnecessary cooling needs but also high improvement potential. It is possible to drastically reduce the heating needs by acting on the envelop and promoting efficient HVAC systems and reducing or even eliminating cooling needs as well as DHW needs by promoting efficient shading, thermal mass and the use of solar collectors.
This work intends to characterize the thermal performance of Portuguese residential buildings identifying their main thermal pathologies resulting from a bad design of the envelope and proposing the most appropriate improvement measures to reduce or even eliminate these pathologies.
To achieve these goals, a thermal diagnostics software tool is being developed taking into account the analysis of the envelope, the HVAC systems and existing pathologies. This tool will help designers to define their rehabilitation strategies towards improved buildings energy performance in a cost/benefit perspective.

**Keywords:** Thermal diagnosis, buildings pathologies, thermal rehabilitation of residential buildings, rehabilitation support tools

## 1. Introduction

Energy production and consumption are the basis for growth of civilization. Global industrial revolution witnessed extensive use of energy and gradually the pattern of energy consumption started shifting toward massive dependence on electricity. For several decades, we all remained unconcerned about the fact that any form of energy is an exhaustible resource and unless these resources are used with required amount of care for avoidance of wasteful consumption, the future generations could even be deprived of the essential supplies for meeting their requirements and needs. It was only in the last few decades that this concern has started getting wider recognition. The fear of rapid depletion of exhaustible energy resources have been compounded with the concerns for global warming and other climate change related issues. It is a fact that larger amount of energy production, in most cases, is associated with larger amount of CO2 emissions [1].
Therefore, all aspects of energy consumption are being dissected with a view to finding out the possible areas of reductions, conservation and saving, so that without affecting the quality and level of services, the amount of consumption of electricity needed could be significantly reduced. All countries in the last years have started looking at the need for efficient consumption of energy. Whether some of them have gone ahead with the implementation of understanding reached in the Kyoto Protocol or not, they have started taking actions which would lead to a more efficient pattern of consumption.
Thus, the imperative to improve energy efficiency is stronger than ever. Energy efficiency must be one of the strategies employed to address the challenges of energy security, climate change and economic development. On this road to a sustainable energy future, actions in the building sector can play a key role. Energy performance of buildings is one of the keys to achieve the EU Climate & Energy objectives, namely the reduction of a 20% of the Greenhouse gases emissions by 2020 and a 20% energy savings by 2020. They account for 40 % of Europe's energy use and a third of its greenhouse gas [2]. Therefore, improving the energy performance of buildings is a cost-effective way of fighting against climate change and improving energy security, while also creating job opportunities, particularly in the building sector.
So, it is evident that energy efficiency in buildings has tremendous potential all over the world, but the greatest potential to save energy is offered by existing buildings. They are responsible for over 40% of the world's total primary energy consumption, and account for 24% of world CO2 emissions [3].
According to Census 2011, in Portugal there are more than 3.5 million buildings, representing approximately 30% of final energy consumption (18% in residential buildings and 12% in service buildings) [4]. The overall analysis of the distribution of energy consumption in the domestic sector in terms of final energy also shows that 68% are

consumed in food preparation and heating of domestic hot water (DHW), 17% on lighting and appliances and 15% in heating and cooling [5].
This shows the significant weight of DHW heating in the overall energy consumption. At this point of view it is possible to conclude that Portugal, as well as other countries in the Mediterranean region, has enormous potential for energy savings in buildings since they have a privileged sun exposure that allows them to take great advantage of passive solar techniques as well as of solar collectors for heating DHW.
However, despite the enormous potential for thermal rehabilitation that Portugal has, its housing stock, although it is relatively recent, is in very bad conditions of conservation due to lack of adequate legislation, the inexperience of those involved in the rehabilitation sector and also the lack of appropriate tools to support decision makers providing them with the best solutions, both technically and economically, to improve the energy performance of a building [6] [7].
So first, this work aims to characterize the thermal pathologies most common in Portugal, which will allow to define the most appropriate measures for improvement and how to apply them correctly.
Secondly, it is also a purpose to develop a tool that assists users in choosing improvement measures that should be implemented to reduce or eliminate the thermal pathologies found and improve the energy performance of the building.

## 2. Methology of the Study

To develop the software tool, an initial analysis was undertaken to assess the state of the art regarding the characterization of the existing housing stock and that consisted of a collection that included the exhaustive literature review of the different types of residential buildings as well as the solutions used to characterize and standardize the existing residential buildings [8].
For this paper they were reviewed 600 buildings distributed by construction period as shown in Figure 1.

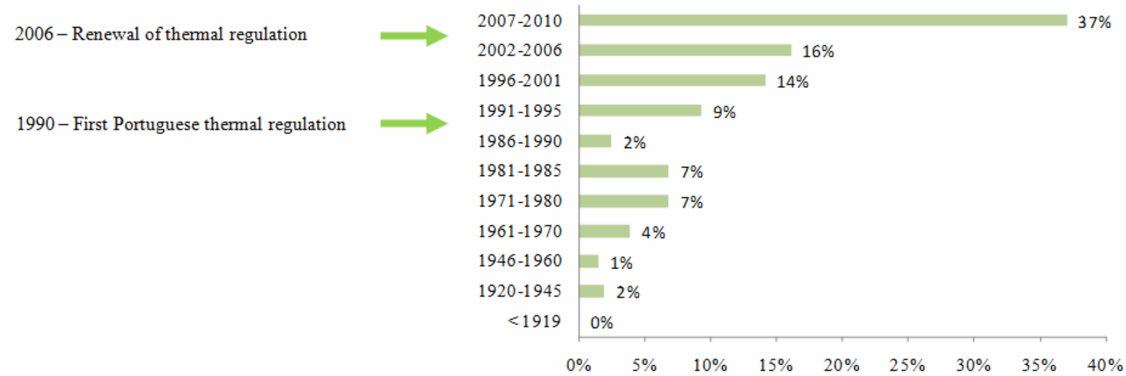


**Figure 1**. Percentage of cases studied for constrution period

Based on information gathered within the literature review, it was decided to divide the thermal pathologies encountered in four major groups: pathologies in facade elements, in roofs, in floors and in glazing. Each of these groups then originated subgroups with the most frequent pathologies. Each of the pathologies observed was recorded as well as the improvement measures proposed to eliminate it [9].
During the study, it was performed a detailed cost-effective analysis of the proposed rehabilitation solutions based on inflation and interest rates. The study also included the assessment of the asset value achieved in the building with the rehabilitation process, along with a detailed cost analysis of each task towards the objective.

## 3. Results

### 3.1. Characterization of thermal pathologies

When analyzing the possibility of including energy efficiency measures in a building it is important not only to consider the degree of deterioration due to various factors, such as the natural aging of materials or lack of maintenance, but also that the current characteristics of buildings can lead to a reduction in its thermal performance and high energy consumption, whether in the cold or warm season [10].
Among the most common anomalies of the buildings, should be mentioned the lack or inadequate thermal insulation of the building envelope, the presence of thermal bridges in the building envelope, degradation of the covering or occurrence of humidity (affecting the energy performance and durability), low thermal performance of glazing (heat loss by heat transfer disproportionate and excessive air leaks), the lack of adequate sun protection of glazing (leading to overheating inside buildings or increased thermal loads and energy requirements in the case of houses with

cooling systems environment) and non-controlled ventilation (creating greater energy needs for heating in winter) or insufficient ventilation (leading to higher relative humidity levels in winter and overheating in summer and the consequent discomfort of the occupants, the phenomena of condensation and low indoor air quality) [11] [12].
Of the 600 cases observed, the pathologies observed had the distribution shown in the following figures 2 and 3.

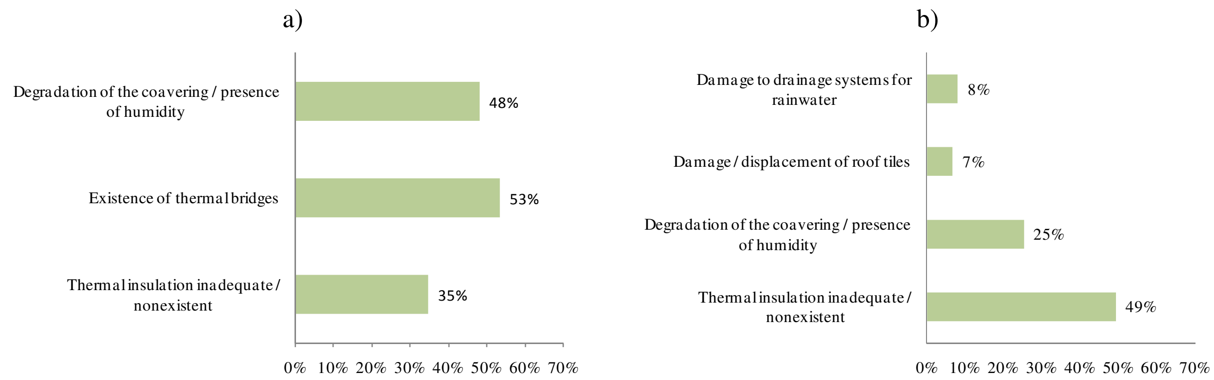


**Figure 2**. Percentage of pathologies evaluated in: a) façade elements, b) roofs

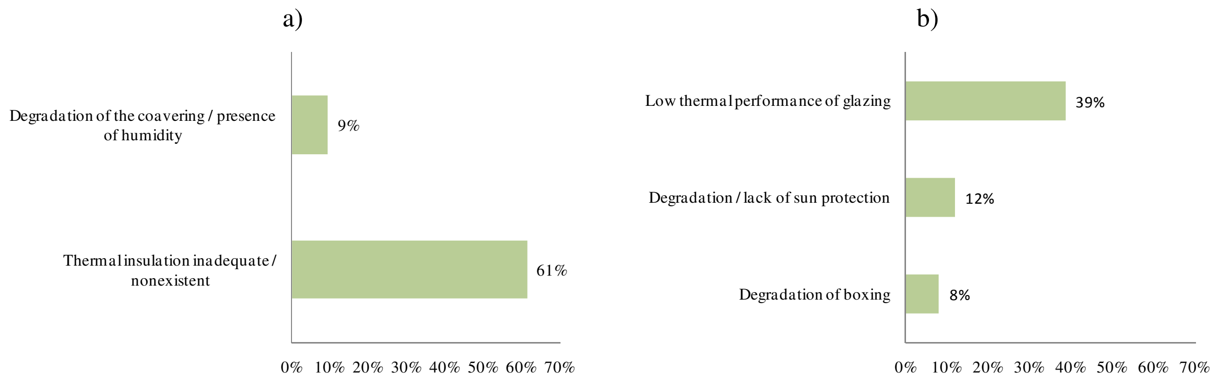


**Figure 3**. Percentage of pathologies evaluated in:a) floors; b) glazing

Although the sample included relatively new buildings in their distribution (with 37% of the buildings built after 2006 - date of entry into force of the renewed thermal regulation, and 76% of the buildings built after 1990 - date of entry into force of the first thermal regulation), it is verified that the Portuguese housing stock shows large gaps in its thermal quality. Indeed, as can be seen in the previous figures, a large part of the buildings studied exhibit degradation in its coverings with the presence of humidity in the walls (48%), roofs (25%) and floors (9%). This is due mainly to lack of insulation in these elements (35% in walls, 49% in roofs and 61% in floors) and the existence of thermal bridges in walls (53%). In the case of glazing it was possible to see that the pathologies found are mainly due to the use of single glazing with low thermal performance (39%) instead of double or triple glazing with better performances.

### 3.2. Improvement measures proposed

Each one of the pathologies observed in the 600 analysed cases was recorded as well as the improvement measures proposed to eliminate them, considering the following order of priority of intervention:

1. Correction of construction pathologies;
2. Reduction of energy needs through intervention on buildings envelope;
3. Use of renewable energy;
4. Use of more efficient systems.

Figure 4 shows the distribution of the proposed improvement measures for the cases under analysis. As it is possible to see, in most cases the proposed improvements encompassed the placement of insulation in the envelope elements, especially on the roofs (71% of cases). These measures allowed not only to improve and eliminate the most common pathologies (presence of humidity and degradation of the coverings), but also reduce the heat losses through opaque envelope.

It was also given particular attention to equipment for heating DHW (62% of cases) given its importance in energy consumption in households having to bet on the placement of more efficient equipments.

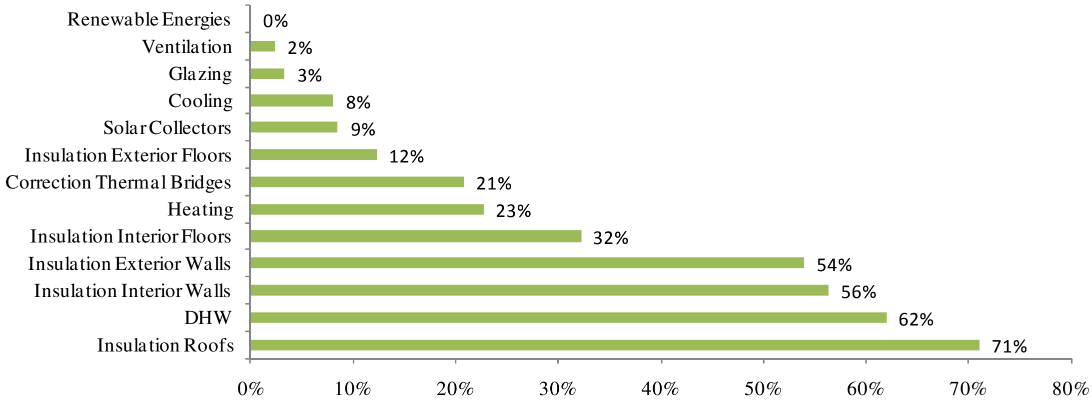


**Figure 4**. Distribution of the proposed improvement measures

### 3.3. Thermal diagnostics software tool

The difficulty shown by stakeholders in the process of energy certification of existing residential buildings in analyze the most appropriate improvement measures to thermally rehabilitate a buildings and reduce or even eliminate their thermal pathologies, allowed the development of a software tool that makes this process easier.
Figure 5 shows the flowchart of the software tool under development.

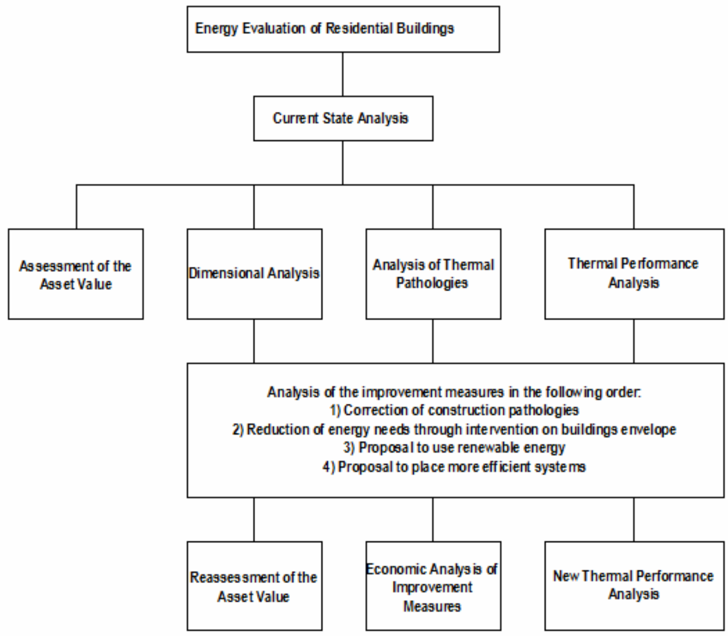


**Figure 5**. Flowchart of software tool

The software will analyze the current state of a building based on a dimensional assessment and characterization of all elements of the envelope (walls, roofs, floors, windows ...) and the characterization of the pathologies found. This initial analysis will also include the study of the building energy performance as well as the determination of the asset value of the property before any measures are implemented.
Based on this information, the tool will then propose the most appropriate measures to improve, both technically and economically, its thermal behavior.
The building energy performance and the asset value of the property will then be re-evaluated with the improvement measures implemented. This economic analysis will evaluate not only the decrease in energy costs but also the increase of asset value, taking into account current interest rates. Figure 6 shows two examples of the software interface.
Figure 6 shows examples of some interfaces of the software tool under development.


**Figure 6**. Examples of software interface

## 4. Conclusions

By the analysis of the graphs shown, it is possible to conclude that, in existing buildings, thermal bridges in façade elements are very frequent and responsible for humidity and moisture problems and degradation of the coverings. Insufficient insulation of roofs and floors are also common situations detected responsible for the very poor thermal performance of existing buildings along with the poor quality of glazing that, in most of the situations, are single glazing.

It is noted that in the studied sample, most of the observed fractions belong to relatively recent buildings (39% between 1991 and 2006 and 37% after 2006).

The data shows that the entry into force of the new thermal regulation, RCCTE, dated from 2006, has not yet been fully assimilated by some of the players, especially those responsible for construction. Too often it appears that buildings constructed after 2006, but before the entry into force of the SCE (Building Energy Certification System), do not meet the minimum requirements imposed by the thermal regulation, thus not complying with the requirements of the projects.

In addition, it appears that designers have some difficulties in analyzing the most appropriate measures to improve the energy performance of a building largely due to the lack of experience, technical studies and regulations in this area.

For these reasons the tool that is being developed is particularly important in the Portuguese context. It is intended that the use of it would not only facilitate the work of designers but also raise the technical quality and efficiency of energy rehabilitation performed allowing to population greater comfort in their homes and significantly reducing unnecessary energy expenditure.

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